Abstract

Wireless Sensor Networks (WSNs) have enhanced the standard of living of mankind with the touch of advanced technology and the manifestations of this fact are found in numerous real-life applications. However, all of these WSN-based applications are *single-user centric*, in which a user-organization owns and deploys its personalized sensor network and typically does not share the accessed data to another party (user/organization). Also, the data sharing policies vary across organizations and an external user-organization is able to retrieve sensor information that is specific only to the region that is administered by the network administrator. Thus, generally, only user-organizations that own a sensor network have satisfactory access to sensor data. To address these issues, recently, *sensor-cloud* infrastructure has been conceived as a potential solution for multi-organization WSN deployment and data access.

Sensor-cloud infrastructure acts as the interface that connects the physical world (attributes of which can be measured using sensor based devices) and the cyber world of inter-computer communication through excellent data scalability, on-demand service provisioning, remote data visualization, and user programmable analysis. The idea of sensor-cloud thrives on the principle of virtualization of physical sensor nodes. The user-organizations possess their own applications, and request the sensor-cloud for retrieval of sensed data. These requests are interpreted within the sensor-cloud environment, and the physical sensor nodes are dynamically consorted to form Virtual Sensors (VSs), as per requirements. Aggregated data from the VSs are transmitted to the end-users in the form of a simple obtainable service (just as electricity, or water), named *Sensors-as-a-Service* (*Se-aaS*). Sensor nodes are hereby transformed from a typical 'hardware' to a simple 'service', which is cheap, convenient, user-friendly, and scalable.

Currently, the principles, ideology, and challenges involved in this paradigm shift from traditional WSNs to sensor-cloud platforms are being explored. However, the technicalities that are required from an implementation perspective, inclusive of the theoretical modeling, experimental analysis, architectural designs, and development of this platform, are unexplored till date. This dissertation focuses to resolve the principal technical challenges associated with the complete conceptualization of sensor-cloud and eventually aims to build a fully-functional prototype of sensor-cloud infrastructure.

A summary of the major works reported in this dissertation is described as follows. From an implementation point of view, the scope of technical and theoretical research have been identified in this domain. Initially, the focus is on the theoretical modeling of virtualization of physical sensor nodes within sensor-cloud. The necessity for this paradigm shift to a sensor-cloud platform is mathematically justified for all WSN-based applications. Eventually, the work endeavors to establish the idea of Se-aaS. Next, the design issues of sensor-cloud platforms are addressed. Conventional data transmission techniques involve periodic packet transmissions from sensor nodes to the cloud-servers for computation, storage, and processing. However, the rate of change of the physical environment may not be reasonably significant, thereby, leading to redundant packet transmissions and inefficient utilization of network resources. In this regard, a dynamic, adaptive, and optimal caching has been designed that preserves the accuracy of information, and conserves the network resources, simultaneously. Followed by this, the economics of the infrastructure is investigated. Within sensor-cloud infrastructure, the end-users utilize the physical sensors and the cloud infrastructure as per their demand and pay as per their usage, to the cloud service provider (CSP). Thus, to quantify the usage of the end-users and charge them accordingly, a dynamic and optimal pricing scheme is designed, specifically for Se-aaS. The networking dimensions of sensor-cloud have also been considered – the problem of routing and channelization of the data of the VSs, originating from multiple regions, to geographically distributed sensor-cloud data centers (DCs) is investigated. To resolve this issue, an algorithm is proposed for the dynamic scheduling of a cloud DC that would serve a particular user application with data from the respective VSs.

Combining the solutions of the afore-mentioned research challenges, a holistic prototype of sensor-cloud infrastructure is developed using real sensor hardware and a real cloud platform. To validate the correctness of the infrastructure, an application-specific scenario of multiple target tracking is investigated and experimented within it. An experiment is also performed using the real (non-simulated) setup to examine the performance of the prototyped sensor-cloud infrastructure in big-data environments. It is observed that the infrastructure performs significantly well in practical scenarios involving real sensor-hardware, huge and voluminous data requests, and large number of end-users.

Keywords: Cloud computing, wireless sensor networks, big data, data centers, energy constraints, pricing, virtualization